8.0 FINDINGS, RECOMMENDATIONS, AND GUIDANCE

This section presents the findings of the safety evaluation team; comparisons between the Astrotech facility and government facilities with a similar function; recommendations of the site evaluation team; and some general guidance for ensuring safe operations at similar industrial facilities. The determinations presented here are based on a physical inspection of the Astrotech facility and viewing some of the hazardous operations, knowledge of existing facilities performing similar operations owned by NASA and the Air Force, interviews with Astrotech staff, questions asked of payload owners that use the facility, and discussions with state regulatory personnel and local and county emergency preparedness and planning agencies.

Overall, Astrotech appears to have taken every reasonable precaution in designing and constructing a facility which is safe for its employees and those living nearby, and in implementing the policies and operating procedures that have been successfully used by DoD and NASA for many years. Astrotech has commissioned safety studies both to initially site the buildings on the property and to analyze the design and construction changes for expansion. Astrotech has also attempted to identify and incorporate as many safety, monitoring, and detection features into the facility as was feasible.

Part of Astrotech's incentive for building and maintaining a safe facility is to convince spacecraft manufacturers that it is prudent and desirable to use the facility. The extremely high value of the payloads processed at the Astrotech facility causes both Astrotech and the spacecraft manufacturers to have a vested interest in ensuring that the Astrotech facility is operated and maintained as safely as possible.

8.1 Findings of the Safety Evaluation Team

The Astrotech facility is a state-of-the-art design for payload processing operations. It was apparent that Astrotech has not only complied with all applicable DoD and NASA requirements, but also sought out additional recommendations from spacecraft manufacturers and owners as well as government agencies during the construction stage and during continuing operations, to ensure maximum safety during efficient operation.

8.1.1 Facility and Procedures

The facility design and operating procedures employed at the Astrotech facility have been successful in ensuring safe operations at the facility in large part due to the personal experience of the General Manager, Safety Officer and others at Astrotech who have had long careers operating and working at payload processing facilities belonging to NASA and the Air Force. It is the direct result of this experience, and the lessons learned during the time spent at these Government facilities, as well as industry-wide input solicited prior to design and construction of the facility, that has enabled Astrotech to build and operate a state-of-the-art commercial facility. This knowledge, experience base, and interest in operating a facility which meets or exceeds the standards set by NASA and the Air Force was apparent to the evaluation team during the on-site inspection and interviews.

Specifically, with regard to the facility and operating procedures, the evaluation team found that:

- The buildings where hazardous materials are handled are separated from the public and from the non-

hazardous work areas by distances determined using DoD and ATF explosives siting criteria. Therefore, if an accident involving an explosion were to occur, the public would not be exposed to any primary explosion effects (i.e., overpressure from the blast, flying fragments, or fire).

- The facility and equipment are state-of-the-art design and quality. Specific example of Astrotech's commitment to continuing improvements are their recent acquisition of portable MDA toxic vapor detectors to supplement the traditional Draeger tube vapor analyzers in monitoring liquid propellant handling and loading operations, and their planned acquisition of a closed-loop distillation system for recovery of freon contaminated during equipment cleaning operations.

- Building 2, is designed to minimize the risk to the public of any potential releases of propellant liquid or vapor that could result from a small spill inside the building. The containment and scrubber systems provide protection to the public from any incidental exposures during normal operations.

- The physical facilities compare favorably to Government facilities that serve similar functions. See Section 8.2 for a more extensive discussion.

- Prior to and during operations, policies and procedures are in place to ensure safety. These include attention to all aspects of operations including such things as customer safety plans and documentation for hazardous operations, careful weather and lightning storm monitoring, proper use of personal protective equipment, inspection and maintenance of facility equipment, and emergency planning.

- The formal, documented procedures for processing payloads meet accepted standards as applied by industry and Government agencies, specifically DoD and NASA.

- No accidents or incidents have occurred at the Astrotech facility since it began operations in 1984 that have required reporting the National Response Center. In fact, in the course of operations only one small spill of anhydrous hydrazine, amounting to less than a teaspoonful, has ever occurred. This spill was completely neutralized by the tank and scrubber systems.

To summarize, the facility and procedures appear more than adequate to safely support the operations that take place at the Astrotech site.

8.1.2 Emergency Response and Preparedness

The evaluation team found in interviews with local and county emergency response and preparedness officials that Astrotech management has been extremely open and cooperative with local public safety officials in the

construction and operation of their Titusville, Florida facility. Through detailed planning, training and equipping, the public safety officials assisted by Astrotech management have been provided means for responding to an accident should one occur. Although there is interest at Astrotech and in the public sector for a joint exercise with county emergency personnel based on a simulated chemical release at Astrotech, no exercise has yet been conducted.

Astrotech's current written emergency response plan has been furnished to local emergency planning and response officials. Identification and management of emergency situations on site would be handled by Astrotech's small and closely-coordinated staff, under the direction of the facility Safety Officer. Procedures are in place and communications equipment is available to protect and evacuate workers in hazardous situations, to summon a facility emergency response team, and to call for off site assistance should it be required.

8.2 Comparison of Astrotech Facility to Comparable Government Facilities

NASA at KSC and the Air Force at CCAFS have a number of payload processing facilities where they have performed operations similar to those that take place at Astrotech. The Government processing facilities, most of which were built 20 to 25 years ago, handle the identical payload systems, ground support equipment, and hazardous materials as Astrotech. These facilities include:

- Delta Payload Spin Test Facility
- Navstar Processing Facility
- Solid Motor Assembly Building
- Shuttle Payload Integration Facility
- Vertical Processing Facility
- Horizontal Processing Facility
- Orbiter Processing Facility
- Vertical Assembly Building

In addition, other hazardous materials operations are conducted at the Propellant Servicing Facility, and the Propellant Conditioning Facility as well as, of course, at the launch pads and related service structures.

The Astrotech facility was designed and constructed by utilizing the safety and operating experience gained by NASA and the Air Force over the past three decades. The safety features and related policies and procedures at the Astrotech facility are a direct benefit from the lessons learned at KSC and CCAFS. Since the processing facility at Astrotech is one of the newest of its kind and the only commercial operation to-date, the facility has consequently taken advantage of and uses state-of-the-art equipment and procedures. Many users of the facility (Astrotech customers) believe it to be superior to the existing facilities located on government property nearby. (See customer letters in Appendix F.)

Because the only other comparable facilities and operations are operated by the Air Force and NASA; because of the close proximity of the Government facilities to Astrotech; and because the Astrotech facility has specifically drawn upon the lessons learned from operations at the Government-operated processing facilities, some discussion of the special features at the Astrotech facility that make it more advanced technologically and safe enough to operate in an industrial park, is warranted here. The specific features which were incorporated by Astrotech and which are believed to be an improvement over the existing DoD and NASA processing facilities are described below.

Vapor Containment

Vapor containment inside Astrotech's Building 2 is a characteristic not found in many older payload processing facilities. The structure was designed and built from the very beginning to be a containment facility in case a small propellant release or spill should occur inside the structure during normal operations. The containment technology has advanced considerably over the last 30 years since the Government-owned facilities were originally designed. This same technology is now, according to Astrotech personnel, being incorporated into the Government-owned hazardous processing facilities which currently vent any stray vapor emissions to the atmosphere.

Electrostatic Dissipation

The floor covering in the high bays is electrostatically dissipating tile. This technology was originally developed for use in hospital operating rooms where static electricity created potentially hazardous situations in handling sensitive equipment. The tiles are vinyl, impregnated with graphite, and are fixed to the floor with a conductive mastic that dissipates static electricity to the building ground system. This reduces considerably the potential for spontaneous electrostatic discharge in an environment where highly flammable liquids and vapors and solid rocket motors could be present. In the older facilities large metal sheets are laid over the floor in the working bay to provide a ground link for dissipation of possible electrical charge buildup, making operations more cumbersome.

Spill Collection and Containment

In the north and south high bays and the north airlock, fueling operations are performed on "fueling islands." These islands are surrounded by a stainless steel propellant collection trench. The fueling island floor does not slope toward the trench, it is extremely flat to ensure payload stability during loading, however, the rest of the floor is very slightly sloped toward the trench. The trench itself is graded and drains toward the underground propellant containment tanks located outside the building. This trench drainage system reduces the "wetted area" of a propellant spill and accommodates containment and cleanup in case of a release. In the event of a fuel spill involving a fire, this system would also serve to confine the fire to the fueling island and help prevent its spread to other areas. The Government facilities have no internal spill containment system.

Remote Visual Access to Hazardous Operations

Explosion-proof observation windows have been installed between the control rooms and the high bays in Building 2. This allows Astrotech and customer payload safety and quality control personnel to observe hazardous operations directly without necessitating their physical presence in the high bay during hazardous operations. Astrotech also has the traditional CCTV monitoring capacity found in the NASA and DoD payload processing facilities. In addition, Astrotech videotapes all fueling operations and makes these tapes available to customers.

Fuel/Oxidizer Containment and Neutralization

A containment system, consisting of oxidizer and fuel holding tanks - with the appropriate valving and manually-switched piping system to separate the tanks - and a scrubber system, has been installed. The scrubber is operated under permit by the Florida DER. Astrotech maintains a check-off procedure and visual verification to ensure proper switching of valves and tanks between hazardous operations. No such containment and neutralization system exists at the government facilities.

Vapor Detectors

At all times that liquid propellants are on site, Astrotech monitors atmospheric conditions in Building 2. They use state-of-the-art toxic vapor detectors to supplement the more conventional Draeger tube vapor analyzers. These new monitors are sensitive and are microprocessor-controlled for speed, accuracy, and specificity. The detectors are enclosed in special clear plastic cases designed for use in potentially flammable or explosive conditions.

Pre-Action Fire Suppression

A pre-action fire suppression system is in place that has compressed air in the lines, maintaining a "dry pipe" condition. The system is activated by two independent but necessary actions: first, a smoke/heat detection alarm signal from any of the mounted detectors or from a manual pull station; and second, an intense heat source sufficient to melt the fusible link in the sprinkler head. The IR smoke/heat detection alarm system (or the manual pull system) opens a valve which then charges the system with water. A high intensity heat source must then be present to melt the fusible plug at the sprinkler head, allowing the sprinkler to wet the area. This system provides some protection for sensitive payloads and other equipment in case there is a false alarm or other problem. Government facilities currently use only wet pipe sprinkler systems.

Computer Monitoring of Alarms

Alarms are automatically sent to the guard house at the front gate by means of a computer link for various parameters and systems including:

- temperature and humidity (HVAC system)
- loss of air pressure in the fire suppression system
- toxic vapor detector alarm
- toxic vapor detector status alarm (low battery or tape break)
- generator failure
- fire alarm

The alarm panel indications displayed to the guard allow prompt identification of potential problems and notification of proper personnel and authorities.

8.3 Specific Recommendations

8.3.1 Equipment, Operations and Procedures

Evaluate the Operations Sequence

Although the probability of a major accident at the Astrotech facility is small, it could possibly be further reduced by modifying the sequence of processing operations. The presently used sequence was established when payloads were loaded and pressurized on the launch pad. However, in recent years the final payload propellant loading, pressurization, and integration with large apogee kick motors has shifted location and now occurs within a payload processing facility. Also, the amounts of liquid propellants and the size of SRMs have increased considerably.

Given these changes in payload processing, the safety evaluation team recommends that Astrotech undertake a study to determine the technical and economic feasibility of altering the operations sequence to further minimize risk. Even though no such study has been completed, it is possible to suggest a modified operations sequence. For example, the modified sequence below minimizes the risks from the greater volume of propellants and takes advantage of the sequencing flexibility available within the payload processing facility.

Present Sequence	Modified Sequence
Oxidizer load	Tank pressurization
Fuel load	Fuel Load
Mate payload and SRMs	Oxidizer load
Tank pressurization	Mate payload and SRMs
Encapsulate and transport	Encapsulate and transport

The general rationale for these changes is to sequence activities to minimize risk by minimizing the opportunities for release of propellants and for interactions between fuel, oxidizer and SRMs. In the modified sequence, the first step is to pressurize the payload high pressure tanks because failure of a tank is most likely to occur during pressurization. In the modified sequence, pressurization is completed prior to the loading of liquid propellants, so that a tank failure could not involve liquid propellants. This would be feasible if the payload design includes valves that isolate the high pressure tanks from the propellant tanks.

The sequences above assume a bipropellant spacecraft, where both fuel and oxidizer are loaded. Because spills or leaks of fuel (i.e., anhydrous hydrazine or MMH) are more likely to result in fires or explosions than spills or leaks of oxidizer alone (i.e., nitrogen tetroxide), in the modified sequence the fuel sampling and loading operations are scheduled before the oxidizer sampling and loading operations. In the present sequence, it is more likely that a fire or explosion resulting from a fuel leak would spread and involve the previously loaded oxidizer.

Because the technical and economic feasibility study necessary to support a recommendation to resequence operations is beyond the scope of this study, and because the safety evaluation team has not examined in detail all possible risks or technical constraints that might arise from the modified sequence, the above discussion should be considered by Astrotech as a beginning point for further evaluation, and not an strictly recommended sequence.

Install Additional Communications Capability in Cart Storage Rooms

Currently, the only communication link from the fuel and oxidizer cart storage rooms is to the control room through an intercom mounted in each cart storage room. The evaluation team recommends that Astrotech consider installing an additional communication link out of the cart storage rooms (e.g., a telephone with an outside line, or an internal connection to the guard house) so that if an individual needed to make outside contact, and no one was present in the control rooms, there would be a communication link.

8.3.2 Safety Policies and Requirements

Define Propellant Loading Sequencing in Safety SOP

In considering the possibility of resequencing the sequence of operations, the safety evaluation team examined the Astrotech Safety Standard Operating Procedures (SOP) to see if any limitations are placed on operations sequencing. As none were found in the SOP, the evaluation team assumed the proposed resequencing may be viable. However, the scrubber procedures checklist[1] does state that fuel must be processed before oxidizer. If the scrubber system operations checklist indicates that there are operational sequencing limitations, these limitations should also be detailed in the SOP, so that payload owner/operators can properly plan their operations.

Specify Training Requirement Criteria

Astrotech requires that payload owner/operator personnel be "properly" trained and that the payload owner/operator "certify" that this training has taken place. However, Astrotech Safety policies do not detail the requirements that, if met, ensure proper training. Although this could be interpreted as a lack of specificity on Astrotech's part, the evaluation team is aware that training requirements are not specified elsewhere in the space launch industry. Because the commercial space industry has a relatively limited number of facilities and personnel, training to date has largely been accomplished through on-the-job apprenticeship, supplemented by applicable courses (e.g., OSHA requirements and the KSC propellant handlers video) in hazardous materials handling. As the industry expands, it will be important to detail the training required before personnel can be given responsibility for certain operations. Of the payload owner/operators that currently use the Astrotech facility, most have teams for specific hazardous payload processing operations (i.e., propulsion teams) that have worked together for long periods of time and have successfully completed many propellant fueling operations. The evaluation team recommends that Astrotech review its criteria for proper training, and also recommends that the industry as a whole evaluate training program availability and content and begin to institutionalize training and certification requirements to ensure competency and an adequately trained work force for the future.

Define Accident Events and Develop Specific Response Procedures

When on the site visit, the evaluation team inquired of Astrotech what their procedures would be in the event of an uncontrollable spill. Although Astrotech clearly stated the necessary activities (e.g., attempt to control spill by turning off valves, evacuate personnel, turn off power and thereby seal the building), the exact sequencing and timing of these activities is not documented in plans and procedures. Although the sequence would vary

[1] Scrubber System Check Lists at Astrotech Space Operations, Inc., Titusville, Florida, Don J. Wade, Manager, Spacecraft Operations, July 18, 1984.

depending on the specific spill event, more thought should be given and a written procedure developed for general types of events. The procedure should include a definition of the accident that initiates the stated response (e.g, a spill of a stated volume of fuel or oxidizer, a vapor monitor reading at a specific level), the actions taken to mitigate and evacuate, and the steps for re-entry at specified vapor concentrations. Specific consideration should be given to determining the capabilities and limitations of the scrubber and tank containment systems for a variety of accident scenarios.

8.3.3 Emergency Planning and Preparedness

Although the current emergency planning and preparedness status of the Astrotech facility appeared to be adequate, the evaluation team has several recommendations for improvements that would facilitate communications and rapid response.

Clarify Astrotech Personnel Assignments

Astrotech places heavy reliance on the knowledge and presence of their Safety Officer in dealing with emergencies. Although all personnel appear to be familiar with the safety procedures, it is important that Astrotech formalize the Safety Officer back-up by assigning a specific person to develop the same detailed familiarity with Astrotech's plans and procedures. By formalizing a Safety Officer back-up, either one person or several individuals who would rotate depending on the shift, two goals would be accomplished: the selected individuals would make an additional effort to learn how to direct implementation of the safety procedures, and in the event of an emergency occurring in the absence of the Safety Officer or one that injured him, all personnel present would know immediately who would assume leadership responsibility, alleviating possible confusion.

An additional personnel consideration is a local media spokesperson. Astrotech's corporate media contact is normally stationed away from the plant. It would be helpful for the facility to have a local spokesperson available to furnish information in coordination with local emergency management officials should an emergency occur. Although the team has assumed that the Safety Officer would take on that role, in the event of an emergency, the Safety Officer's other duties would likely be so time consuming that a different person would be preferable for the media contact.

Expand Emergency Contact Lists

Astrotech's procedures depend solely on the emergency telephone number 911 as an entry point into the outside emergency system. Their notification list needs to be expanded to include telephone numbers of other critical contacts in the local emergency management system (i.e., county emergency management director) for reinforcement.

Astrotech's plan should also include a list of contact persons and telephone numbers for its nearest industrial neighbors, since a situation could arise that would require Astrotech to notify them. The local emergency management agency should be able to assist in compiling such a list.

Circulate SARA Title III Reporting Requirements

Three chemicals which are on-site periodically at Astrotech depending on the specific spacecraft being processed, have been designated as hazardous substances under CERCLA. Two of these chemicals are listed as Extremely Hazardous Substances (EHSs) under SARA Title III. SARA has specific reporting requirements for facilities to follow when designated amounts of these substances are accidentally released into the environment. Information required in these reports is itemized in Section 304 of Title III. Astrotech needs to identify these items specifically in its plans and procedures and indicate that they are to be furnished when reporting a release.

In the event of a reportable release of a CERCLA chemical, Astrotech should furnish the same information as that required for the EHSs. In order to ensure proper implementation of the reporting requirements, Astrotech should include the reportable quantity for each chemical that it handles on the notification list.

Exercise Emergency Plan with Local Authorities

Astrotech should schedule, if possible, a full scale exercise of its emergency plan with local authorities. If scheduling of the full scale exercise continues to present difficulties, at least a tabletop exercise should be scheduled.

8.4 General Guidance for Ensuring Safe Operations

The safety evaluation team brought to the Astrotech Safety Evaluation a wide range and depth of expertise in issues necessary to ensure safe operations at a payload processing facility. Knowledge of payload processing procedures, hazardous characteristics of specific materials, emergency planning requirements, and other applicable regulations was necessary to evaluate the facility completely. In the event that communities are working with other existing facilities to evaluate risk, or industrial facilities are seeking to initiate or expand operations, the safety evaluation team has prepared general guidance for ensuring safe operations. These general observations are not aimed at the Astrotech facility, in fact in many cases,

Astrotech has followed or exceeded the guidelines that the team has identified and could be used as an example for effectively implementing them.

Many industries handle and use hazardous chemicals in a variety of operations and processes under varying handling conditions (e.g., high or low temperatures, high pressures) at locations throughout the United States. The occurrence of accidents at major industrial facilities in the chemical and petrochemical processing industries that have caused injury or death has focused both public and government attention on safety, training, emergency preparedness and planning, and accident prevention. When an industry is considering siting a facility or expanding its operations in an area, the first step is to consider prior assessments of safety or hazards analyses for similar facilities in terms of such things as siting criteria and safety designs. Astrotech accomplished this step by surveying operators of Government facilities and potential customers for design suggestions, and by commissioning a safety expert to evaluate compliance with siting criteria.

It is critical to coordinate early with the local planning officials and begin by laying out the overall plans for siting, design, and construction regarding safety and accident prevention especially if chemicals will be handled on site that should be included in the community emergency preparedness and planning efforts. At this point it may be advisable to bring in safety experts to help make decisions about where to expend time and resources to maximize safety by including special designs or safety systems or by adapting operations sequences.

In general the components of an adequate safety program at a facility include not only the design, but also operating and maintenance controls, training, documentation and record keeping, and internal audits and inspections. The overall safety program at a facility is a key factor in protecting the public and the environment. Proactive programs designed to prevent chemical releases are the most effective way to protect community health and safety and the environment. To prevent accidents, a facility must anticipate the circumstances that could result in releases and include precautionary and preemptive actions appropriate to the nature of the hazardous chemical(s) handled as well as the operations at the site.

Existing safety, health, and environmental audit programs established at a facility are important in improving emergency response and risk reduction. It is critical to identify facility hazards, carefully evaluate the associated risks presented by the hazards and if possible, reduce those risks to prevent and mitigate the effects of releases. This can be effectively achieved through communication and cooperation between industry and government to prevent or minimize accidents.

An additional assurance of safe operations can be implemented by establishing a regular monitoring program for industries in a local area. Although many federal, state and local authorities monitor industrial facilities for compliance with specific regulations (e.g., at Astrotech the City of Titusville tests neutralized liquid before accepting it into the sewer), generally there is no established authority that ensures a facility is complying with its own internal safety requirements. Although the broad general scope of this Astrotech Safety Evaluation is not likely to be frequently repeated, it would be reasonable and useful for an expert to annually monitor and observe that established safety procedures are implemented at industrial facilities.

Some of the equipment or procedures that may be considered in addressing safety and accident prevention include:

1. All equipment used in handling hazardous chemicals

2. Safety procedures addressing:

   -storage tanks
   -piping
   -pressure relief, venting, scrubbing systems
   -secondary containment systems
   -detection, warning or alarm systems
   -emergency shut-down and fail safe systems
   -critical controls and interlocks
   -safety training
   -checklists for critical safety activities
   -inspection, maintenance, repair or replacement of critical safety systems
   -loss of power or utilities
   -emergency procedures for employee evacuation and notification of emergency responders and nearby neighbors

Additional information of interest may include the accident history of facility or of the industry in general, local weather patterns, proximity to water sources, any nearby businesses or residences, and any special facilities (e.g., hospitals or schools) or environmentally sensitive areas in the vicinity.

Many groups in the U.S. and in the international community have been developing methods to provide technical guidance to assist in the evaluation of industrial safety. The Environmental Protection Agency, the Federal Emergency Management Agency, and the U.S. Department of Transportation have all coordinated to publish documents that are also important to these issues. Private groups and industrial trade associations have also addressed these issues. One particularly helpful industrial association, the American Institute of Chemical Engineers (AIChE) has established the Center for Chemical Process Safety (CCPS). This group is a leader in producing guidelines for hazard investigations and evaluations, establishing industrial safety guidelines, and developing and improving industrial safety procedures. Many of the new publications by CCPS may be of use in looking at safety, risk management, and accident prevention programs. These references and others are listed in Appendix G, which provides an overview of references that deal with safety, hazards evaluation, risk management and release prevention programs.